Low Latency Handoff by Integrating Pre-Registration with MIFA "PRE-MIFA"

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Abstract: *All IP networks become increasingly visible. The various communication networks are aimed to be connected with each other through a common IP core, so that the user will stay always online, anytime and anywhere. However, a lot of challenges remain unsolved until today. One of the major challenges is how to achieve a seamless and fast handoff while moving from one point off attachment to another. In this paper we propose a new fast and smooth handoff approach called Pre-MIFA (pre registration mobile IP fast authentication protocol). Pre-MIFA uses the layer 2 trigger to eliminate the latency resulting from the agent discovery procedure (pre-registration method), and the MIFA procedures to eliminate the latency resulting from the communication between the foreign agent and the home agent especially when the home gent is far a way from the foreign agent. Our approach minimizes the handoff latency without introducing intermediate node and without making any restriction on network topology. We also present a simple program analysis comparing the hand off latency of MIP, MIFA, Pre-Registration and our approach. Our results have shown that Pre-MIFA outperforms Pre-Registration method, MIP and MIFA with respect to handoff latency.*

Keywords: *Low latency, mobile IP, performance analysis.*

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1. Introduction

The growing number of portable computing devices and the requirement to provide seamless connectivity to the global internet using end to end IP solution for Mobile users have simulated the research into IP mobility protocols.

Mobile Internet Protocol MIP is the current standard solution for mobility management in IP networks [10]. It allows the Mobile Node MN to change its point of attachment from Foreign Agent (FA) to another FA. Establishment of new tunnels can introduce considerable delays in the handoff process due to the round-trip time between FA and the Home Agent HA during the registration process. Handoff latencies affect the service quality of real-time applications of mobile users. With MIP, the handoff latency highly depends on the distance, i.e., delay between HA and FA.

Many approaches developed to support a fast handoff as Hierarchal Mobile IP (HMIP) [7] which minimizes handoff latency but depends on additional network element introduced on the path between HA and FA. Pre-registration method are also introduced to eliminate the time needed for agent discovery but the problems of MIP due to transmission delay between the HA and the FA remain.

Mobile IP Fast Authentication Protocol MIFA is introduced to minimize the handoff latency by delegating the authentication to the New Foreign Agent NFA instead of HA, thus the time to inform the HA about the new binding and to establish a new tunnel is eliminated [5]. In this paper, we introduce a new technique by making integration between pre-registration and MIFA Pre-MIFA, as a result MIFA doesn't need to wait until Layer 2 (L2) handoff finished receiving L2 link up L2-LU to enable MN to send Registration Request (Reg- Rqst) to the NFA but it will use pre-registration method to start handoff in advance.

In this paper we provide a simulation program to compare the handoff delay of MIP, MIFA, Pre-Registration and Pre-MIFA. Our results have indicated that Pre-MIFA outperforms MIP, Pre-Registration and MIFA with respect to handoff latency.

The rest of this paper is organized as follow: in sections 2 and 3 we provide a short description of MIP and the approaches used to solve the handoff latency. Our proposal is introduced in section 4, performance analysis of our approach is presented in section 5 and finally the conclusion is introduced in section 6.

2. Mobile IP (MIP)

Mobile IP (MIP) [10] is a protocol that keep track of mobile's where about and delivers Internet messages to the mobile at its current location. MIP is the standard solution for mobility management in IP-based systems. MIP expands the network in a way that it contains two more entities which HA and FA.

The MN gets two IP addresses. The first address, referred to as a home address identifies the MN in its home network. The second IP address, termed as a

Care of Address (COA), determines the current point of attachment. Using MIP the MN has to registered and authenticated by the HA every time it moves from the responsibility of one FA to another. This introduces extra latency to the communication, especially when the HA is far a way from the FA.

3. How to Solve the Handoff Latency?

Many approaches are proposed to solve the handoff latency [10]. HMIP minimizes handoff latencies but depends on additional network elements introduced on the path between HA and FA. The need for additional network elements contradicts with the principles of the internet and impedes the wide use of HMIP in a world wide network.

Proposals for low latency handoffs use a trigger originating from L2-trigger to anticipate handoffs prior to a break of the radio link. In methods for pre-registration, post-registration and a combined method have been proposed [1]. Thus, a layer 3 Hand Off (L3-HO) is triggered by a L2-trigger. With the pre-registration method, the MN scans the medium for other FAs if the strength of the signal received from the current FA deteriorates or if the error rate increases. If another FA is available, a L2-trigger is fired. This prompts the MN to register with the NFA through the old one. Thus, the L3-HO is performed while the MN performs L2-HO. The L2-trigger may be fired not only by the MN, but also by the current FA or even the NFA. When the radio link of the current FA is turned down, i.e., the current FA receives a layer 2 Link Down trigger (L2-LD) the current FA forwards the packets directly to the NFA.

The post-registration method works as follows: If the MN notices that the link with the current FA is not adequate; it tries to move to a neighboring FA. In case the FA belongs to another subnet, it informs the current FA about the possible movement and performs only L2-HO. If the link between the current FA and the MN breaks down (receiving L2-LD trigger), a bidirectional tunnel (downlink and uplink) is established between the Old FA (OFA) and the new one. When the L2-HO is finished, the MN can register with the NFA while receiving the packets. Thus, the MN receives the packets before the registration. Even though Post-Registration is faster than Pre-Registration, the impact of delayed L2-triggers with Post-Registration is the same as with Pre-Registration. Due to the missing MIP registration with the Post-Registration approach, the packet delay is larger (uplink and downlink). The combined method i.e., to try pre-registration first and to use post-registration if it fails inherits the problems of the both approaches. In this approach the MN scans for other FAs similar to the Pre- and Post-Registration methods. When the MN notices that a handoff is necessary, it informs the current FA about this and registers with the NFA through the old one similar to the Pre- Registration approach. However, the old FA forwards the packets directly to the NFA without waiting of L2-LD trigger.

When the NFA receives a Registration Replay (Reg-Rply) from the HA and the link to the MN is established (receiving the Link Up trigger), it forwards Reg-Rply message and the packets forwarded from the previous FA and from the HA to the MN. However, the problems of MIP due to transmission delays between the HA and the FA remain.

Mobile IP Fast Authentication Protocol (MIFA) 4 has been developed to eliminate the latency sources existing in MIP and to match the real-time requirements. Basic operation of MIFA is illustrated in Figure 1.

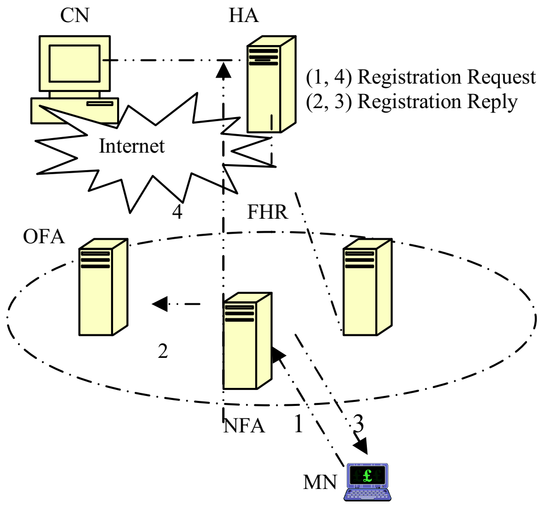

Figure 1. Basic operation of MIFA 4.

Using MIFA the time needed to communicate with the HA is hidden from the application. This is due to delegating the authentication to the FA. This local authentication relies on layer 3 - Frequent Handoff Regions (L3-FHRs). Each FA establishes a L3-FHR containing all adjacent FAs, the MN may move to. Therefore, the MN only needs to contact the FA to become re-registered and to resume the right to receive and to send data. Another main advantage of MIFA is that it has simple flat network architecture 5.

While the MN communicates with the current FA, this FA sends Move Probability Notification (M_P_Not) messages to all of the FAs in the L3-FHR, to which the current FA belongs to. These notifications contain the security associations between the MN and the FAs in this L3-FHR on one side and between the FAs and the HA on the other side 2.These security associations are recorded in a soft state and can only be used by one FA in the future and deleted from the others. Additionally, these notifications contain the characters of the HA. These characters enable the FA to decide if the requirements of the MN can be satisfied by the HA. These notifications are authenticated by means of the security associations established between the FAs in the L3-FHR. When the

MN moves to one of the FAs in the L3-FHR, to which the previous FA belongs to, it sends a Reg-Rqst message to this FA. A local authentication and authorization of the MN is performed in the NFA. If the authentication succeeds, the FA generates a Previous FA Notification (P_FA_Not) message to inform the previous FA that it has to forward the packets, destined to the MN, to the current FA. After that the current FA sends a Reg-Rply to the MN. At this time the MN can resume transmitting and receiving data. Additionally, the current FA sends a HA Notification (HA-Not) message to inform the HA about the new binding. The HA in turn establishes a new tunnel to the NFA. After that it intercepts the packets forwarded to the old binding and tunnels them to the new one. Thus the time to inform the HA about the new binding and to establish a new tunnel is eliminated.

4. The Integration Between Pre-Registration and MIFA (PRE-MIFA)

Pre-MIFA is the integration between MIFA and pre-registration such that MIFA can use the information originating from the L2 trigger to eliminate the time needed for agent discovery [4].

Trigger is a signal related to the L2-HO process, a first trigger that is used is an early notice of an upcoming change in the L2 point of attachment of the MN (L2 trigger), a second trigger, the link down trigger (L2-LD), indicate that the L2 link between the MN and the OFA is down. The link up trigger (L2-LU) occurs when the L2 link between the MN and the NFA is established. The MN uses the regular MIP procedure for initial registration and informs the FA and the HA that it prefer to use Pre-MIFA in next registration. As a response to this, the HA and the FA will act as in MIFA protocol which explained before.

As shown in Figure 6, when the MN notices that the quality of the current link deteriorates, it starts to scan the medium for other available FAs. If the detected FA belongs to another subnet, a L2-trigger is fired. The L2-trigger is used to identify the next FA, which normally belongs to the same L3-FHR the current FA belongs to. This trigger prompts the MN to start the L3-HO. As a result the MN sends Proxy Router Solicitation message (PRSol) to the current FA. However in the PRSol message the MN asks the current FA to send an advertisement on behalf of the NFA. The current FA sends a Proxy Router Advertisement (PRAdv) as a response to this solicitation. This message contains the CoA of the NFA. Next, the MN sends Reg-Rqst to the current FA, which in turn, checks the MN-FA authentication information. The current FA then encrypts the security association between the MN and the NFA (K2MN-FA) and the security association between the NFA and the HA (K2FA-HA) with the security associations between the FAs in the L3-FHR (KFA, FA). After that the current FA adds these encrypted keys, the authentication values sent previously from the HA and the HAs characters to the Reg-Rqst. The current FA then authenticates this message by using KFA, FA and sends it to the NFA.

This NFA checks at first the authentication between it and the MN, this authentication will be checked by using the security association sent from the previous FA with the notification. After that the current FA checks the MIFA information, which presents the authentication information (between the MN and the HA) the MN has to generate. The current FA then checks if the requirements requested from the HA can be satisfied, this can be achieved through the check of the HAs characters sent with the notification too. If the authentication succeeds, the FA builds a P-FA-NOT message to inform the previous FA that it has to forward the packets, sent to the MN, to the NFA, When L2-LD trigger is received. The NFA buffers these packets until L2-LU is received to forward it to MN.

After that the NFA generates two new random variables R1, R2 and K3FA, HA, which will be used to authenticate the messages between the HA and the next FA when the MN performs the next registration and encrypts them with K2FA, HA. The NFA then sends R1, R2 and K3FA, HA with a HA-NoT message to the HA to inform it about the new binding, this message is authenticated by using K2FA, HA. The HA in turn sends HA-ACK as a response. This message contains the HAs characters and the authentication values the MN has to generate in the next registration.

When NFA receive L2-LU trigger, the NFA doesn't need to wait until HA-ACK received because NFA has delegation to authenticate MN as in MIFA, Thus the NFA will send Reg-Rply to MN. After that the MN resumes receiving and transmitting of packets.

When HA-ACK is received by NFA, it generates a key to be used to authenticate the messages exchanged between the MN and the next FA in the next registration (K3MN, FA), encrypts this key with K2MN, FA and sends this key and the newly generated random variables R1, R2 with Reg-Rply message to the MN. the HA in turn establishes a new tunnel to the NFA, after that it intercepts the packets forwarded to the old binding and tunnels them to the new one. Thus the time to inform the HA about the new binding and to establish a new tunnel is eliminated MIFA protocol and the time needed for agent discovery is eliminated by Pre-Registration method Our proposal reduces handoff latency to be nearly equal to the layer 2 hand off latency.

5. Program Description

We have designed a program to compare the proposed solution (Pre-MIFA) with Pre-Registration, MIP, and

MIFA according to the handoff delay, we define the following terms:

- To: The time at which the handoff begins.
- T (X,Y): The time required to pass through the link from node X to Y.
- P (MN): The processing time required by the MN during the registration.
- P (OFA): The processing time required by the OFA during the registration.
- P (NFA): The processing time required by the NFA during the registration.
- P (HA): The processing time required by the HA during the registration.
- TMN-U: The time required by the MN to resume transmission in uplink.
- TMN-D: The time required by the MN to resume receiving in downlink.

We assume that the speed of the packets is the same between all agents (OFA, HA, NFA, MN) so the time will be factor of the distance between the agents.

5.1. Handoff Delay by Using MIP

According to MIP operation shown in Figure 2, when the MN moves to foreign network, it must be first perform agent discovery by sending PRSol to the NFA which respond by sending PRAdv to the MN. After that the MN perform registration process by sending Reg-Rqst message to the NFA which process it and send HA-NOT to the HA. The HA reply by sending HA-ACK to the NFA which process it and send Reg-Rply to the MN.

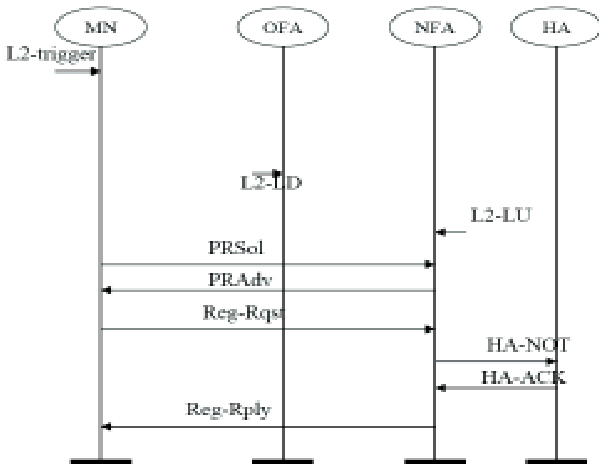

Figure 2. Operation of MIP [10].

We construct a simulation program shown in Figure 3 to determine the time needed by the MN to resume receiving and transmitting data in uplink and downlink (TMN-U, TMN-D).

The program illustrates the following results:

The time at which the L2-LD appeared is (by observing Figure 5 we can determine the TL2-D and TL2-U as follows):

$$TL2\text{-}LD \approx T0 + 3 * T(OFA,MN) + 2 * P(OFA) + P(MN) + T(OFA,NFA) + P(NFA) \quad (1)$$

The time at which the L2-LU appeared is:

$$TL2\text{-}LU \approx TL2\text{-}LD + P(OFA) + P(HA) + T(HA,NFA) + T(NFA,OFA) \quad (2)$$

The time at which the MN can resume transmission and receiving packets in uplink and downlink:

$$TMN\text{-}U = TMN\text{-}D = TL2\text{-}LU + 3 * P(NFA) + 2 * P(MN) + P(HA) + 4 * T(NFA,MN) + 2 * T(HA,NFA) \quad (3)$$

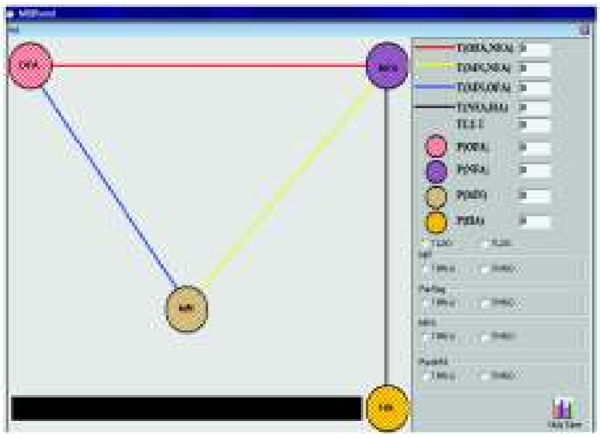

Figure 3. Simulation program for handoff delay.

5.2. Handoff Delay by Using MIFA

The operation of MIFA protocol is shown in Figure 4.

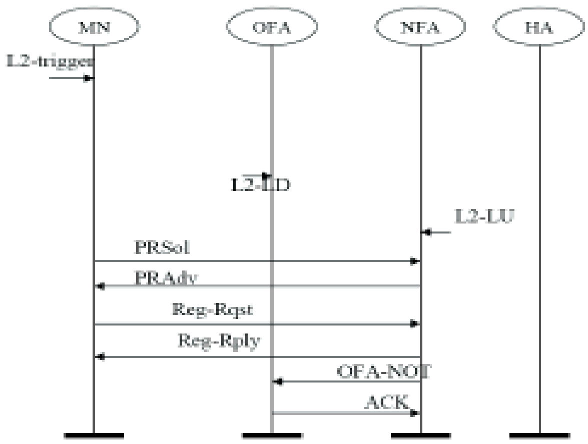

Figure 4. Operation of MIFA [3].

The same simulation program shown in Figure 3 is applied on MIFA to compute the time required by the MN to resume transmitting and receiving packets through the uplink and downlink. The program illustrates the following results: The time at which the MN can resume transmitting packets through the uplink:

$$TMN\text{-}U = TL2\text{-}U + 2 * P(NFA) + 4 * T(NFA, MN) + 2 * P(MN) \quad (4)$$

The time at which the MN can resume receiving packets through the downlink:

$$TMN\text{-}D = TL2\text{-}U + 3{*}T\,(MN,NFA) + 3{*}P\,(NFA) + 2{*}T\,(NFA,OFA) + P\,(MN) + P\,(OFA) \quad (5)$$

5.3. Handoff Delay by Using Pre-Registration Method

The operation of Pre-Registration method is shown in Figure 5.

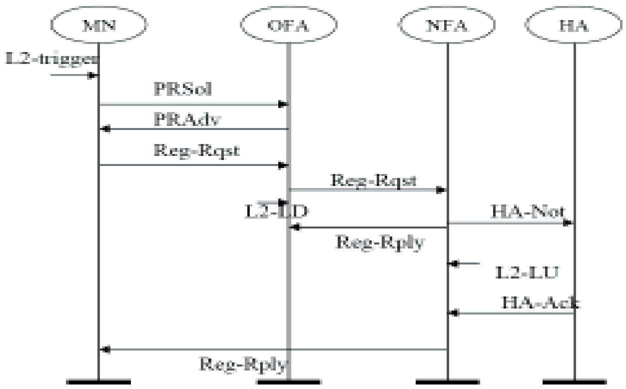

Figure 5. Operation of Pre-Registration [1].

The same simulation program shown in Figure 3 is applied on Pre-Registration method. The program illustrates the following results: The time at which the MN can resume transmitting and receiving packets through the uplink and downlink:

$$TMN\text{-}U = TMN\text{-}D = TL2\text{-}U + P\,(NFA) + T\,(NFA,MN) + T\,(HA,NFA) + P(MN) \quad (6)$$

5.4. Handoff Delay by Using Pre-MIFA

The operation of Pre-MIFA method is shown in Figure 6. The same simulation program shown in Figure 3 is applied on Pre-MIFA protocol to compute the time required by the MN to resume transmitting and receiving packets through the uplink and downlink. The program illustrates the following results:
The time at which the MN can resume transmitting packets through the uplink:

$$TMN\text{-}U = TL2\text{-}U + T\,(NFA,MN) + P\,(MN) \quad (7)$$

The time at which the MN can resume receiving packets through the downlink:

$$TMN\text{-}D = TL2\text{-}U \quad (8)$$

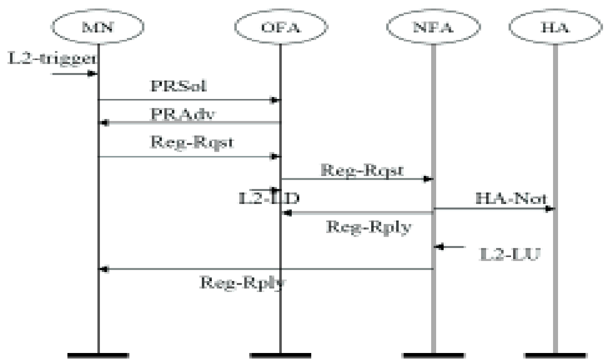

Figure 6. Operation of Pre-MIFA.

5.5. Program Results

We extended our program as shown in Figure 7 to compare between the four cases by applying different values for variables on the previous equations from equation 1 to equation 8.

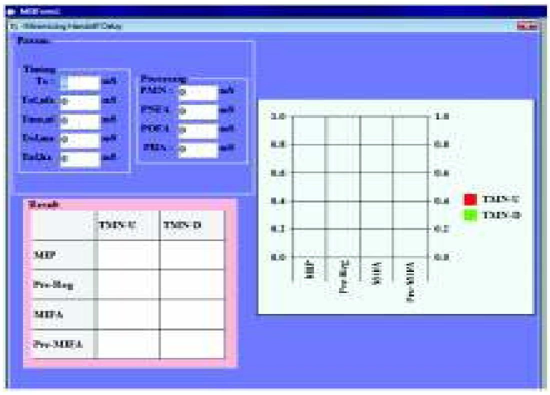

Figure 7. Analysis program to determine handoff delay for MIP, MIFA, Pre-Registration, Pre-MIFA.

By applying different values for T0, T(OFA,NFA), T(MN,NFA), T(NFA,HA), T(OFA,MN), P(MN), P(OFA), P(NFA), P(HA) we found that the Pre-MIFA is the best method for all cases. For example we applied the following values on the program:

$T0 = 0$
$T\,(OFA, NFA) = T\,(MN, NFA) = T\,(MN, NFA) = 5\ ms$
$T\,(NFA, HA) = 50\ ms$
$P\,(MN) = P\,(OFA) = P\,(NFA) = P\,(HA) = 5\ ms$

The result of the program appeared in Figure 8.

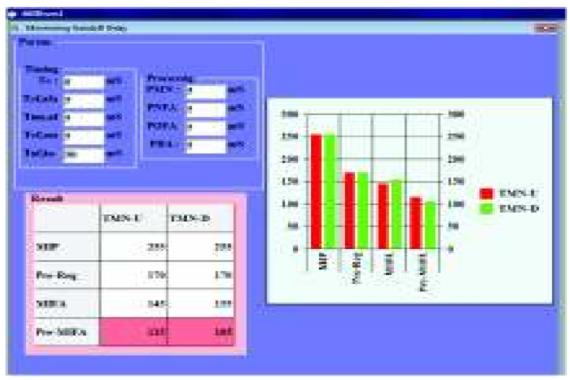

Figure 8. The result of the comparison between MIP, MIFA, Pre-Registration, Pre-MIFA.

By observing the result we found that:

- The best method that enables the MN to resume receiving the packets in the downlink is the Pre-MIFA (105 ms).
- The best method that enables the MN to resume transmitting the packets in the uplink is the Pre-MIFA (115 ms).
- Pre-MIFA method eliminate the time needed for agent discovery (Pre-Registration method) and the communication between the NFA and the HA (MIFA protocol).

- As the distance between the NFA and the HA increased the efficient of Pre-MIFA increased related to the other methods.
- As the parameters changed to other values, Pre-MIFA still as the best method that achieve minimum handoff delay.
- The method that achieves the minimum handoff delay is the Pre-MIFA which is highlighted by the program.

6. Conclusions

We studied one of the basic problems of MIP which is the handoff delay and we introduced the solution called Pre-MIFA. We confirmed our opinion by designing program to compare the proposed solution with the other ones. The results indicated that Pre-MIFA clearly outperforms the Pre-Registration method, MIP and MIFA with a respect to handoff latency.

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